High-performance planar holographic structures for complex focusing of terahertz beams

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High-performance planar holographic structures for complex focusing of terahertz beams

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Abstract-We overview the research results on electromagnetic optimization and experimental realization of low- and high-aspect plasmonic structures designed for simple and sophisticated focusing at the frequencies of 0.35 and 0.65 THz. The structures are considered both in the reflect- and transmit-array configurations whose surface phase distribution is synthesized with a computer holography technique. The overall diffraction efficiency reaching 80% is experimentally demonstrated. The methods of structure fabrication using UV and deep X-ray lithography are discussed.

Last years, searching for effective ways to a complex wavefront manipulation becomes a hot topic in physics of metamaterials [1-5]. This task is evaluated to be important for various applications where beam-shaping and beam-focusing structures are highly demanded, especially in the relatively young terahertz (THz) domain which occasionally faces the lack of high-performance devices of this kind. Using plasmonic structures with a properly designed spatial-dependent reflection/transmission phase, which is normally synthesized by methods of computer holography, such a problem can be elegantly solved [2-5]. As a result, the holographic meta-structures (HMSs) turn out to be purely flat and thin devices with striking functionalities and high efficiency typically unreachable in conventional optics.

In this work, we present the results of electromagnetic optimization and experimental implementation for high-performance THz HMSs of several types, which are tested in the experiments on radiation focusing into the focal areas of simple and complicated shapes including single and several spaced spots, as well as "Latin letters" (Fig.1). The HMSs of the first kind are the reflect-arrays optimized for operation at the frequency of 0.35 THz. In a basic design they are realized as a single-layer photolithographically-patterned metasurface laying upon a grounded polypropylene slab 190 um thick [5]. To cover the range of 360° phase variation, we employed the "patch-to-SRR" topological morphing to attain the polarization-sensitive focusing [5], while and the "patch-to-ring" transformation was utilized for the polarization-insensitive case. The HMSs of the second kind are represented by the transmit-arrays optimized for 0.65 THz, which are made as the single-layer high-aspect structures with a wavelength-comparable thickness. We proposed a relatively simple but effective method for their fabrication, which is based on deep X-ray lithographic patterning of a carrying PMMA layer followed by its entire surface metallization [6, 7].

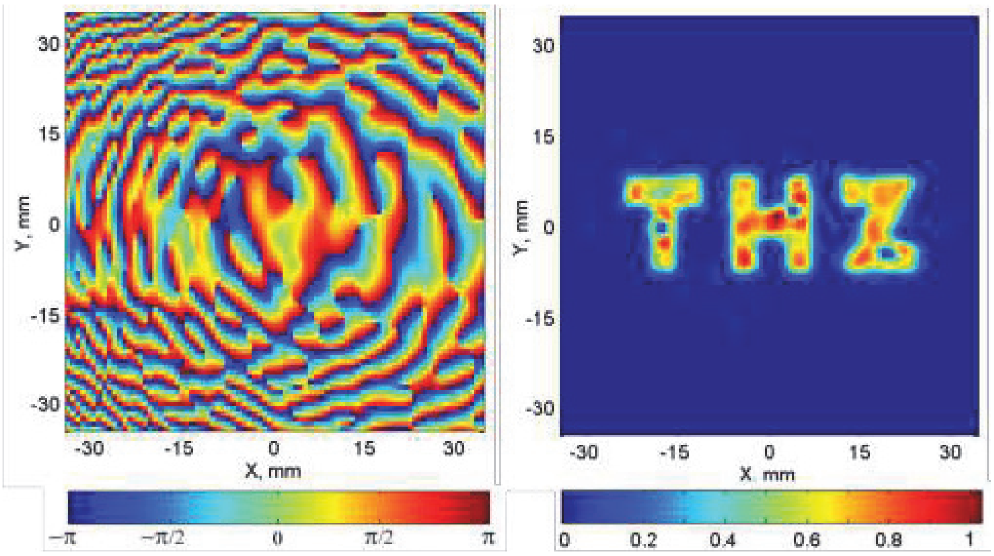

Figure 1. Example of the optimized surface phase distribution (left) for the holographic reflectarray designed to focus a Gaussian beam into the letters "THZ" at 0.35 THz. The right graph shows the measured intensity distribution in the focal plane positioned at F=120 mm from the HMS center (90^0-reflection scheme, see [5]).

To attain the required phase distribution over the HMSs surface, all the developed HMSs were designed via the Gerchberg-Saxton holographic algorithm [5] which was mastered to maximize the diffraction efficiency (DE) of the HMSs. This allowed us to reach ~80% for the experimentally measured DE values. Such a high efficiency outperforms similar characteristics of many analogues operating at THz frequencies and demonstrates the effectual way in creating relatively inexpensive, flat, light-weight, and high-performance focusing devices.

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